

WHAT IS CLAIMED IS:

1. An encoder that operates on data represented in a source sequence of symbols, comprising:

primary encoding means for encoding the source sequence of symbols into a first sequence of codewords;

interleaving means for performing intra-block and inter-block permutations on the source sequence of symbols to produce a sequence of interleaved symbols; and

secondary encoding means for encoding the sequence of interleaved symbols into a second sequence of codewords.

2. The encoder of claim 1, wherein the interleaving means interleaves a sequence of input symbols to produce a sequence of output symbols and includes:

means for grouping the sequence of input symbols into a sequence of blocks;

means for permuting the input symbols within each block of the sequence of blocks into a sequence of intra-permuted symbols;

means for grouping the sequence of intra-permuted symbols into a sequence of intra-permuted blocks; and

means for permuting the symbols of the sequence of intra-permuted blocks across the intra-permuted blocks into the sequence of output symbols.

3. The encoder of claim 2, further comprising output means that combines and sends the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium.

4. The encoder of claim 3, wherein the medium is one of a communications channel, ambient space, and a storage device.

5. A decoder that operates on data represented in a sequence of received symbols, wherein the sequence of received symbols comprises a source sequence of symbols and a first and a second sequence of codewords, comprising:

primary decoding means for decoding the first sequence of codewords in combination with the source sequence of symbols to produce a sequence of primary decoded symbols;

interleaving means for performing intra-block and inter-block permutations on the source sequence of symbols and the sequence of primary decoded symbols to produce a sequence of interleaved symbols and a sequence of intermediate symbols, respectively;

secondary decoding means for decoding the second sequence of codewords in combination with the sequence of interleaved symbols and the sequence of intermediate symbols to produce a sequence of secondary decoded symbols; and

de-interleaving means for performing inter-block and intra-block permutations on the sequence of secondary decoded symbols to produce a sequence of estimated symbols.

6. The decoder of claim 5, wherein the interleaving means operates on an interleaver sequence of input symbols to produce an interleaver sequence of output symbols and includes:

means for grouping the interleaver sequence of input symbols into an interleaver sequence of blocks;

means for permuting the symbols within each block of the interleaver sequence of blocks into a sequence of intra-permuted symbols;

means for grouping the sequence of intra-permuted symbols into a sequence of intra-permuted blocks; and

means for permuting the symbols of the sequence of intra-permuted blocks across the intra-permuted blocks into the interleaver sequence of output symbols.

7. The decoder of claim 6, wherein the de-interleaving means operates on a de-interleaver sequence of input symbols to produce a de-interleaver sequence of output symbols such that the de-interleaving means reverses the intra-block and inter-block permutations performed by the interleaving means.

8. The decoder of claim 7, wherein the secondary decoding means operates in parallel with the primary decoding means and begins decoding after the primary decoding means decodes a predetermined number of codewords in the first sequence of codewords.

9. The decoder of claim 8, wherein a medium provides the sequence of received symbols.

10. The decoder of claim 9, wherein the medium is one of a communications channel, ambient space, and a storage device.

11. The decoder of claim 8, wherein the primary decoding means and the secondary decoding means employ a decoding algorithm to produce the sequence of primary decoded symbols and the sequence of secondary decoded symbols, respectively.

12. The decoder of claim 11, wherein the decoding algorithm uses a symbol reliability equation.

13. The decoder of claim 5, wherein

the primary decoding means includes a plurality of primary decoding means for decoding the first sequence of codewords in combination with the source sequence of symbols to produce a plurality of respective sequences of primary decoded symbols, and

the secondary decoding means includes a plurality of secondary decoding means for decoding the second sequence of codewords in combination with the sequence of interleaved symbols to produce a plurality of respective sequences of secondary decoded symbols.

14. The decoder of claim 13, wherein the plurality of sequences of primary decoded symbols are interleaved by the interleaving means to produce a plurality of respective sequences of intermediate symbols and the plurality of sequences of the secondary decoded symbols are de-interleaved by the de-interleaving means to produce a plurality of respective sequences of estimated symbols.

15. The decoder of claim 14, wherein an  $l^{\text{th}}$  one of the plurality of sequences of intermediate symbols is used by an  $l^{\text{th}}$  one of the plurality of secondary decoding means, and an  $l^{\text{th}}$  one of the plurality of sequences of estimated symbols is used by an  $(l+1)^{\text{th}}$  one of the plurality primary decoding means.

16. The decoder of claim 15, wherein all primary and secondary decoding means operate in parallel.

17. The decoder of claim 16, wherein all primary decoding means start decoding after respective pre-determined numbers of codewords are decoded in the second sequence of codewords and all secondary decoding means start decoding after

respective pre-determined numbers of codewords are decoded in the first sequence of codewords.

18. A system that operates on data represented in a source sequence of symbols, comprising:

primary encoding means for encoding the source sequence of symbols into a first sequence of codewords;

first interleaving means for performing intra-block and inter-block permutations on the source sequence of symbols to produce a sequence of interleaved symbols;

secondary encoding means for encoding the sequence of interleaved symbols into a second sequence of codewords;

output means for combining and sending the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium as a sequence of received symbols;

receiving means for receiving the sequence of received symbols from the medium;

primary decoding means for decoding the first sequence of codewords in combination with the source sequence of symbols to produce a sequence of primary decoded symbols;

second interleaving means for performing intra-block and inter-block permutations on the source sequence of symbols and the sequence of primary decoded symbols to produce a sequence of decoder interleaved symbols and a sequence of intermediate symbols, respectively;

secondary decoding means for decoding the second sequence of codewords in combination with the sequence of decoder interleaved symbols and the sequence of intermediate symbols to produce a sequence of secondary decoded symbols; and

de-interleaving means for performing inter-block and intra-block permutations on the sequence of secondary decoded symbols to produce a sequence of estimated symbols.

19. A system that operates on data represented in a source sequence of symbols, comprising:

primary encoding means for encoding the source sequence of symbols into a first sequence of codewords;

first interleaving means for interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of interleaved symbols;

secondary encoding means for encoding the sequence of interleaved symbols into a second sequence of codewords;

output means for combining and sending the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium as the sequence of received symbols;

receiving means for receiving the sequence of received symbols from the medium;

a plurality of primary decoding means for decoding the first sequence of codewords in combination with the source sequence of symbols to produce a plurality of sequences of primary decoded symbols;

second interleaving means for interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of decoder interleaved symbols;

a plurality of intermediate interleaving means for interleaving the plurality of sequences of primary decoded symbols using intra-block and inter-block permutations to produce a plurality of respective sequences of intermediate symbols;

a plurality of secondary decoding means for decoding the second sequence of codewords in combination with the sequence of decoder interleaved symbols to produce a plurality of sequences of secondary decoded symbols; and

a plurality of de-interleaving means for de-interleaving the plurality of sequences of the secondary decoded symbols to produce a plurality of respective sequences of estimated symbols,

wherein

an 1<sup>th</sup> one of the plurality of secondary decoding means for decoding the second sequence of codewords uses an 1<sup>th</sup> one of the plurality of sequences of intermediate symbols, and

an (1+1)<sup>th</sup> one of the plurality of primary decoding means for decoding the first sequence of codewords uses an 1<sup>th</sup> one of the plurality of the sequences of estimated symbols.

20. A method for encoding data represented in a source sequence of symbols, comprising:

encoding the source sequence of symbols into a first sequence of codewords;

interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of interleaved symbols; and

encoding the sequence of interleaved symbols into a second sequence of codewords.

21. The method of claim 20, wherein the interleaving comprises:

grouping a sequence of input symbols into a sequence of blocks;

permuting the input symbols within each block of the sequence of blocks into a sequence of intra-permuted symbols;

grouping the sequence of intra-permuted symbols into a sequence of intra-permuted blocks; and

permuting the symbols of the sequence of intra-permuted blocks across the intra-permuted blocks into a sequence of output symbols.

22. The method of claim 21, further comprising:

combining and sending the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium.

23. The method of claim 22 further including providing the medium as one of a communications channel, ambient space, and a storage device.

24. A method for decoding data represented in a sequence of received symbols, wherein the sequence of received symbols comprises a source sequence of symbols to be estimated and a first and a second sequence of codewords to be decoded, comprising:

decoding the first sequence of codewords in combination with the source sequence of symbols to produce a sequence of primary decoded symbols;



interleaving the source sequence of symbols and the sequence of primary decoded symbols using intra-block and inter-block permutations to produce a sequence of interleaved symbols and a sequence of intermediate symbols, respectively;

decoding the second sequence of codewords in combination with the sequence of interleaved symbols and the sequence of intermediate symbols to produce a sequence of secondary decoded symbols; and

de-interleaving the sequence of secondary decoded symbols using inter-block and intra-block permutations to produce a sequence of estimated symbols.

25. The method of claim 24, wherein the interleaving comprises:

grouping a sequence of input symbols into a sequence of blocks;

permuting the input symbols within each block of the sequence of blocks into a sequence of intra-permuted symbols;

grouping the sequence of intra-permuted symbols into a sequence of intra-permuted blocks; and

permuting the symbols of the sequence of intra-permuted blocks across the intra-permuted blocks into a sequence of output symbols.

26. The method of claim 25, wherein the de-interleaving comprises:

reversing the intra-block and inter-block permutations performed by the interleaving on a de-interleaver sequence of input symbols to produce a de-interleaver sequence of output symbols.

27. The method of claim 26, further comprising obtaining the sequence of received symbols from a medium.

28. The method of claim 27, further includes providing the medium as one of a communications channel, ambient space, and a storage device.

29. The method of claim 26, wherein the decoding of the first sequence of codewords and the decoding of the second sequence of codewords employ a decoder algorithm to produce the sequence of primary decoded symbols and the sequence of secondary decoded symbols, respectively.

30. The method of claim 23, wherein  
decoding the first sequence of codewords includes decoding the first sequence of codewords into a plurality of sequences of primary decoded symbols, and  
decoding the second sequence of codewords includes decoding the second sequence of codewords into a plurality of sequences of secondary decoded symbols.

31. The method of claim 30, further comprising:  
interleaving the plurality of sequences of primary decoded symbols to produce a plurality of respective sequences of intermediate symbols; and  
de-interleaving the plurality of sequences of secondary decoded symbols to produce a plurality of respective sequences of estimated symbols.

32. The method of claim 31, wherein  
decoding the second sequence of codewords into an  $l^{\text{th}}$  one of the plurality of sequences of secondary decoded symbols uses an  $l^{\text{th}}$  one of the plurality of sequences of intermediate symbols, and

decoding the first sequence of codewords into an  $(l+1)^{\text{th}}$  one of the plurality of sequences of primary decoded symbols uses an  $l^{\text{th}}$  one of the plurality of sequences of estimated symbols.

33. A method for operating on data represented in a source sequence of symbols, comprising:

encoding the source sequence of symbols into a first sequence of codewords;

interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of interleaved symbols;

encoding the sequence of interleaved symbols into a second sequence of codewords;

combining and sending the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium as the sequence of received symbols;

receiving the sequence of received symbols from the medium;

decoding the first sequence of codewords in combination with the source sequence of symbols to produce a sequence of primary decoded symbols;

interleaving the source sequence of symbols and the sequence of primary decoded symbols using intra-block and inter-block permutations to produce a sequence of decoder interleaved symbols and a sequence of intermediate symbols, respectively;

decoding the second sequence of codewords in combination with the sequence of decoder interleaved symbols and the sequence of intermediate symbols to produce a sequence of secondary decoded symbols; and

de-interleaving the sequence of secondary decoded symbols using inter-block and intra-block permutations to produce a sequence of estimated symbols.

34. A method for operating on data represented in a source sequence of symbols, comprising:

encoding the source sequence of symbols into a first sequence of codewords;  
interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of interleaved symbols;

encoding the sequence of interleaved symbols into a second sequence of codewords;

combining and sending the source sequence of symbols, the first sequence of codewords, and the second sequence of codewords to a medium as the sequence of received symbols;

receiving the sequence of received symbols from the medium;

decoding the first sequence of codewords in combination with the source sequence of symbols to produce a plurality of sequences of primary decoded symbols;

interleaving the source sequence of symbols using intra-block and inter-block permutations to produce a sequence of decoder interleaved symbols;

interleaving the plurality of sequences of primary decoded symbols using intra-block and inter-block permutations to produce a plurality of respective sequences of intermediate symbols;

decoding the second sequence of codewords in combination with the sequence of decoder interleaved symbols to produce a plurality of sequences of secondary decoded symbols; and

de-interleaving the plurality of sequences of secondary decoded symbols to produce a plurality of respective sequences of estimated symbols,

wherein

decoding the second sequence of codewords in combination with the sequence of decoder interleaved symbols to produce an  $l^{\text{th}}$  one of the plurality of sequences of secondary decoded symbols uses an  $l^{\text{th}}$  one of the plurality of sequences of intermediate symbols, and

decoding the first sequence of codewords in combination with the source sequence of symbols to produce an  $(l+1)^{\text{th}}$  one of the plurality of sequences of primary decoded symbols uses an  $l^{\text{th}}$  one of the plurality of sequences of estimated symbols.

35. A device used for interleaving in turbo codes, comprising:

means for performing intra-block permutations on a sequence of symbols to produce an intra-block permuted sequence; and

means for performing inter-block permutations on the intra-block permuted sequence of symbols,

36. The device of claim 35, wherein the means for performing intra-block permutations re-orders symbols within blocks of the sequence of symbols of a first length.

37. The device of claim 35, wherein the means for performing inter-block permutations re-order symbols within blocks of the intra-block permuted sequence of symbols of a second length.

38. A device used for de-interleaving in turbo codes, comprising:

means for performing permutations on a sequence of symbols to reverse intra-block permutations and produce a reverse intra-permuted sequence; and

means for performing permutations on the reverse intra-permuted sequence to reverse inter-block permutations.

39. A method for interleaving in turbo codes, comprising:  
performing intra-block permutations on a sequence of symbols to produce an intra-block permuted sequence; and  
performing inter-block permutations on the intra-block permuted sequence of symbols,
40. The method of claim 39, wherein performing intra-block permutations re-orders symbols within blocks of the sequence of symbols of a first length.
41. The method of claim 39, wherein performing inter-block permutations re-order symbols within blocks of the intra-block permuted sequence of symbols of a second length.
42. The method of claim 39, wherein the intra-block and inter-block permutations are performed simultaneously.
43. A method for de-interleaving in turbo codes, comprising:  
performing permutations on a sequence of symbols to reverse intra-block and inter-block permutations.
44. A method for de-interleaving in turbo codes, comprising:  
performing permutations to reverse intra-block and inter-block permutations simultaneously.